Orbiting Carbon Observatory–2 (OCO-2)

Warn Level, Bias Correction, and Lite File Product Description

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Lite Files, Bias Correction, and Warn Level

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For use on Version 8r data

Overview

This document provides the details of the content of the V8r release of the OCO-2 Lite files. Lite files are created to provide a reduced file volume as well as all of the data for one day in a single file. The reduced data volume comes from selecting the limited number of variables to be included.

In addition, the files contain XCO2_raw, which corresponds to the data in the L2Std and L2Dia files, as well as XCO_2, which has had a bias correction applied to it. The file follows the standards of the ESA GHG CCI file format, and thus XCO_2 in these files has a different meaning then in the OCO-2 L2Std and L2Dia files.

Data screening information is contained in the quality flag and the warn levels, which are described in more detail later in the document. Figure 1 illustrates maps of monthly data that is contained in the Lite files, after quality screening is applied.

The main-level XCO_2 data has also been adjusted using a linear bias correction scheme, similar to the approach described in Wunch et al. (2011). Similar to deriving quality flags, we use different XCO_2 truth proxies to allow us to identify and remove XCO_2 biases. In this data release, a number of truth proxies have been used to derive and validate the XCO_2 bias correction parameters, including

- The Southern Hemisphere approximation (see Wunch et al., 2011).
- TCCON (as seen in nadir, glint and target modes)
- The "Small Area Analysis", in which XCO_2 is assumed to be constant for observations taken over distances <~ 100 km within the same orbit.
- A multi-model mean, using 6 models that have all assimilated in-situ data, and only using soundings for which all the model values agree with each other to within a specified tolerance.

Note that the specific bias correction parameters employed in this release are given in the global metadata of each Lite file. (For example, Bias_Correction_land, with the corresponding footprint-specific corrections given in Footprint_bias_land).

Quality Filtering

There are two methods one can use to quality filter the soundings contained in the Lite data files. The simplest method is to use **xco2_quality_flag**, which is simply a byte array of 0s and 1s. This filter has been derived by comparing retrieved XCO_2 for a subset of the data to various truth proxies, and identifying thresholds for different variables that correlate with poor data quality. It applies a number of quality filters based on retrieved or auxiliary variables that correlate with excessive XCO_2 scatter or bias.

The alternative method for OCO-2 and is called the "warn level" approach. This is similar to the above method but is a graduated method that is more nuanced than a simple "yes/no" approach. In this approach, each sounding is given a **warn_level**, which may take a value from 0-5. 0 is considered the highest quality, while 5 is the lowest quality. If you wish to use this approach for your application, we recommend you study how your results depend on the warn level you used for quality filtering. For more details on this approach, see Mandrake et al. (2013).

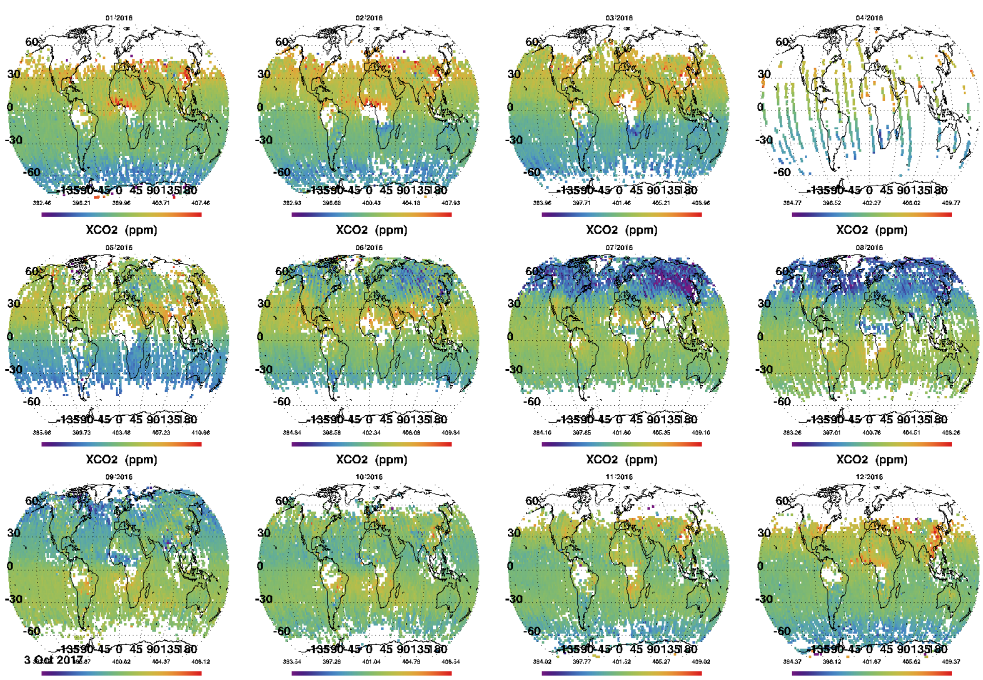


Figure 1: Maps of OCO-2 XCO_2 data after bias correction for 2015. Each panel has a dynamically selected range, which spans 7.5 ppm, centered on that month's distribution of XCO_2.

Bias Correction

The bias correction (BC) maps the original XCO_2 retrievals of the OCO-2 L2 algorithm to our best estimate of XCO_2. We used V8 data spanning from November of 2014 through May of 2015. The BC approach implemented in the Lite files uses regional analysis to identify, within the OCO-2 XCO_2 data records themselves, which terms best predict bias (or Unexplained Variance (%UV)) in the retrievals. Our definition of %UV always uses a null-hypothesis denominator for ease of comparison.

We have constructed several training datasets for our bias correction, such that the set provides an approximation that permits us to define the XCO_2 truth against which the retrievals are evaluated while attempting to insure that real XCO_2 atmospheric gradients are not removed by in the BC.

We use the same two regionally-based training sets used to create the WLs to search for features that predict anomalous variations in XCO_2. As a reminder, the first is the Southern Hemisphere Approximation (SHA), as described in Wunch et al. (2011), in which we assume quasi-constant XCO_2 between 25°S and 60°S latitude during the training period. This method incorporates heterogeneous environments across three continents and surrounding ocean into a single training set that can be used to study what features of the retrieval produce variation in the measured XCO_2. We used several methods to evaluate the sensitivity of the bias evaluation with respect to error in the assumption of invariant XCO_2 in the training set. While the SH XCO_2 data from TCCON provides some guidance (figure 6), several other methods were explored including use of model fields. We find that both the bias features selected and the sensitivity of XCO_2 with respect to these features is relatively insensitive to how the small temporal and latitudinal gradients between 25°S and 60°S latitude are parameterized.

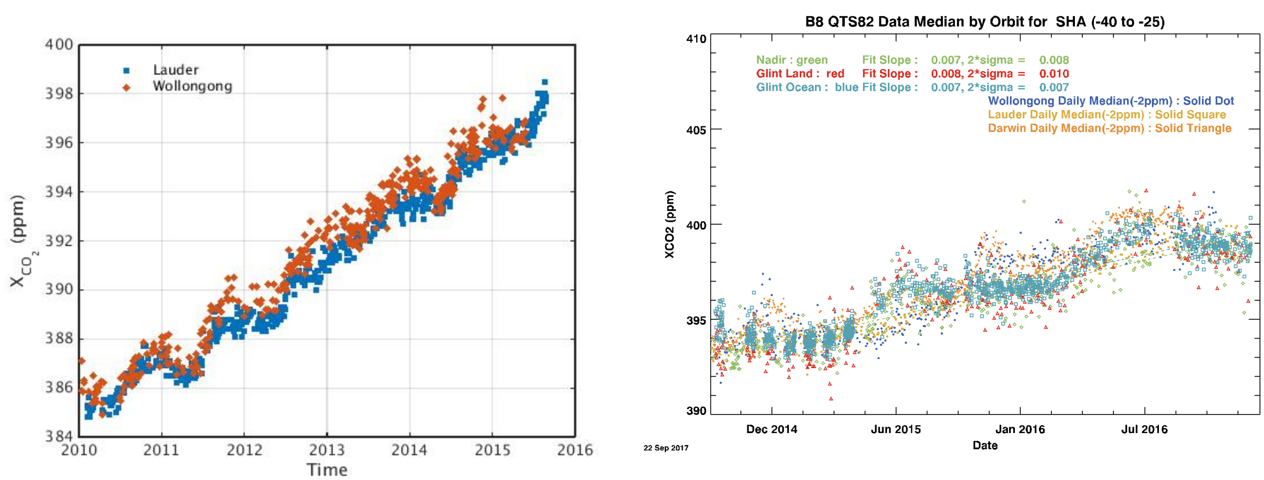


Figure 2: TCCON data in the southern hemisphere show small latitude gradients and seasonal cycles south of 25°S. In the left panel, the Lauder (45°S) and Wollongong

(34.4°S) TCCON time series are shown from 2010 to the present. There is a small (~1 ppm amplitude) seasonal cycle, and an overall secular increase (~2.2 ppm/yr). The Wollongong data are higher than the Lauder data by ~0. 5 ppm, leading to a latitudinal gradient of ~0.05 ppm/degree. The right panel shows the data during November 2014 through December 2016 and includes other southern hemisphere TCCON stations (Darwin and Reunion Island) that are north of 25°S. We limit the SHA to south of 25°S, as the Darwin and Reunion data show significantly more seasonal variations.

The second training set is created using Small Area analysis in which we identify groups of dense soundings (20-80) obtained in spatially-small neighborhoods (<0.9° latitude) obtained within the same orbit (e.g within ~30 seconds). We assume that XCO_2 is constant over these very small areas, and that any XCO_2 variation is an artifact of the retrieval. We expect that except in regions of intense sources or sinks of CO2 (e.g. urban regions) or along frontal systems true variation in XCO_2 is much smaller than the variance produced by the L2 algorithm. As shown in Figure 3, these groupings are globally distributed, sampling a wider heterogeneity than the southern hemisphere.

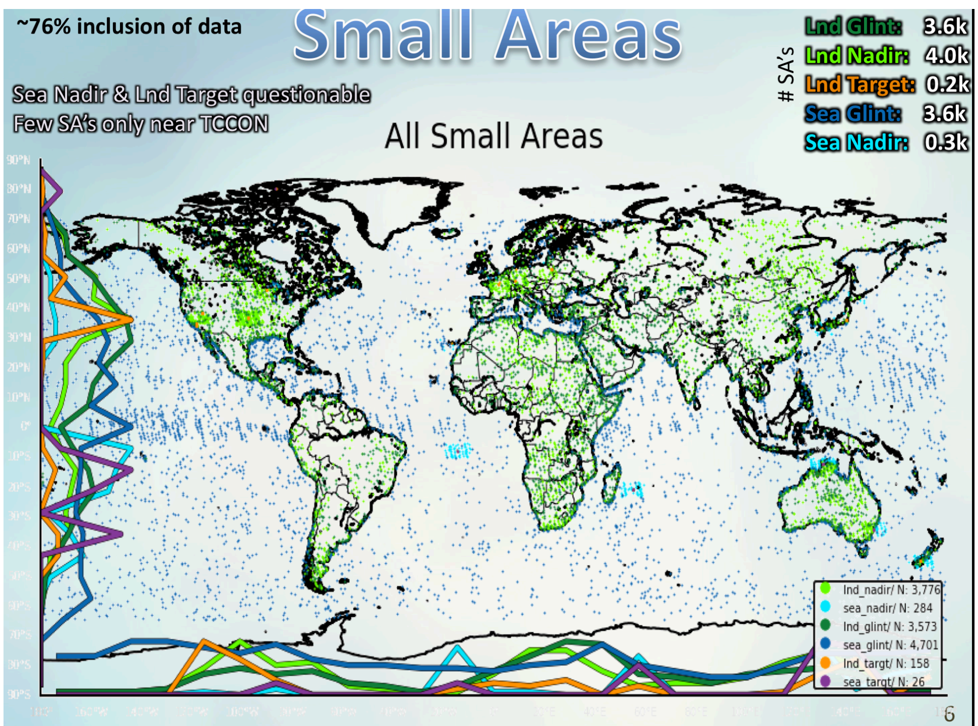


Figure 3 – Location of small areas used in Bias Correction

Note that in the bias correction, TCCON data are used only to define a global offset between the OCO-2 data and the WMO in situ scale as a final step.

The three steps of BC determination are as follows, made concrete by highlighting terms in the final bias correction equation:

$$XCO_{2\,Corrected} = \frac{XCO_{2\,Raw} - FOOT[fp, mode] - FEATS[mode]}{TCCON\_ADJUST[mode]}$$

Step 1) Removing Footprint Bias (term FOOT)

OCO-2 obtains 8 side-by-side, simultaneous, nearly-collocated measurement scenes called footprints. Although the XCO_2 retrievals made from these soundings should, on average, be identical, there are small and highly statistically significant differences. These undoubtedly arise from imprecision in the L1 calibration.

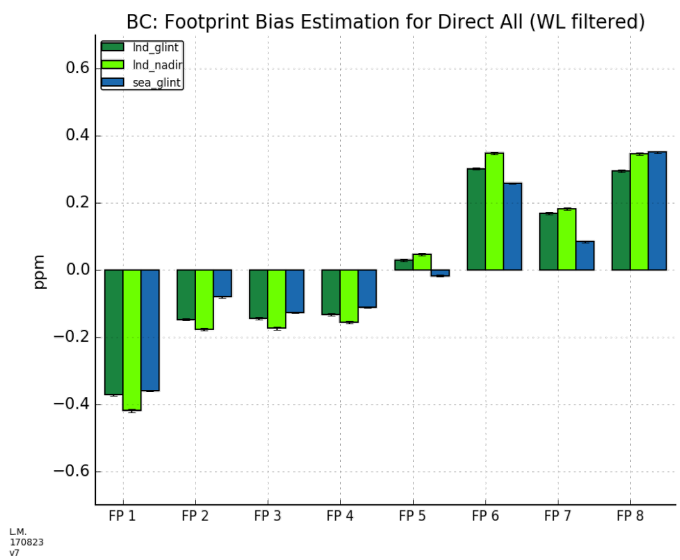


Figure 4 – Footprint Bias vs. Mode

For the V8 data set, we examined highly filtered data grouped into small areas. For most modes, the data set contained millions of soundings, so they were further down selected to only include the best data. Data were selected for the analysis when all 8 footprints in one sounding frame (ID) converged. We computed the median XCO_2 as the "ground truth" value, and subtracted this from the observed XCO_2 to calculate the deviations for each footprint. The reported values are the average of the differences across all soundings per footprint. The filtration resulted in land selections near bright, clear regions such as deserts. The footprint offsets are listed in Table 2 under the term FOOT and shown in Figure 8. Once obtained, they may be subtracted from all sounding XCO_2 in preparation for the next steps of BC.

$$XCO_{2\,Corrected} = \frac{XCO_{2\,Raw} - FOOT[fp, mode] - FEATS[mode]}{TCCON\_ADJUST[mode]}$$

Step 2) Identify unphysical XCO_2 variability (term FEATS)

In this second step, we identify variables retrieved simultaneously with XCO_2 that are correlated with spurious XCO_2 variability using a multivariate linear regression. This is the procedure followed by nearly all GOSAT XCO_2 bias corrections to date (e.g. Wunch et al. 2011, Guerlet et al. 2013).

Several approaches were used to explore this large space of features in the L2 and preprocessing fields: 1) a genetic algorithm that preserves pairwise and higher relationships between features vs. all possible warn level filtration options (Mandrake et al., 2013); 2) a simpler search that sequentially adds the single most %UV-reducing feature from a smaller, expert-curated feature set; and 3) a traditional linear regression sensitivity analysis, again upon a smaller expert-chosen feature set. Using these approaches, we identified four variables that appear to drive approximately half of the %UV in both the SHA and SAA training sets. The different analysis regions and modes have minor differences in the order of features chosen, but the overall features selected and their slopes are remarkably consistent. Table 1 shows for the Land Nadir small area and Sea Glint small area set, the reduction in unexplained variance (UV in %) as features are added to the bias correction fit using three different WL filtration levels:

Table 1: Features used in bias correction with reduction in unexplained variance in parentheses

LAND (NADIR AND GLINT MODE)

		N	Sigma [ppm]	dP	Co2_grad_del	DWS
TCCON:	LandN	106K	1.81 → 1.28	-0.37 (31%)	-0.027 (16%)	-8.0 (4%)
	LandG	76K	1.91→ 1.34	-0.38 (36%)	-0.026 (13%)	-5.1 (2%)
	LandT	314K	1.60 → 1.18	-0.26 (16%)	-0.025 (24%)	-6.9 (5%)
MODELS:	LandN	336K	1.70 → 1.17	-0.34 (27%)	-0.029 (19%)	-8.5 (7%)
	LandG	372K	1.77 → 1.20	-0.34 (29%)	-0.027 (18%)	-8.2 (7%)
SAA:	LandN	275K	1.58 → 0.87	-0.34 (34%)	-0.031 (24%)	-9.9 (11%)
	LandG	286K	1.67→ 0.90	-0.37 (45%)	-0.029 (20%)	-7.9 (6%)
SHA_Mod:	LandN	98K	1.54 → 0.96	-0.35 (29%)	-0.031 (25%)	-8.5 (8%)
	LandG	99K	1.63 → 0.97	-0.36 (30%)	-0.029 (22%)	-9.8 (12%)
Ensemble Statistics		-	- Excluding land Target →	**-0.346 ± 0.035 (-0.356 ± 0.016)**	**-0.028 ± 0.002 (-0.029 ± 0.002)**	**-8.1 ± 1.5 (-8.2 ± 1.5)**
B70		-	-	**-0.30**	**-0.028**	**-7 to -11**

OCEAN GLINT MODE

		N	Sigma [ppm]	dP	Co2_grad_del<-6
TCCON:	WL<=2	71K	0.96 → 0.82	-0.24 (24%)	0.063 (1.8%)
	Chris	73K	0.96 → 0.82	-0.23 (25%)	0.066 (3%)
MODELS:	WL<=2	607K	1.00 → 0.78	-0.23 (33%)	0.106 (6%)
	Chris	647K	1.02 → 0.77	-0.24 (36%)	0.104 (8%)
SAA:	WL<=2	324K	0.77 → 0.44	-0.22 (60%)	0.094 (7%)
	Chris	368K	0.80 → 0.44	-0.23 (61%)	0.088 (9%)
SHA_Mod:	WL<=2	155K	0.83 → 0.68	-0.11 (14%)	0.155 (18%)
	Chris	164K	0.83 → 0.67	-0.11 (14%)	0.135 (21%)
Ensemble Stats (Chris)	**(No SHA_Mod)**	**-**	**-**	**-0.20 ± 0.06** **-0.233 ± 0.01**	**0.098 ± 0.029** **0.086 ± 0.019**
B70		**-**	**-**	**-0.08** **(there was evidence this was too weak)**	**0.077**

These terms are the differences between the retrieved and the *a priori* surface pressure (dP), the retrieved abundance of coarse aerosol (e.g. dust, sea salt, or water clouds), and (very large and unphysical) variation in the retrieved vertical profile of CO_2 (parameter co2_grad_del) from that assumed in the prior.

There is a fundamentally-different bias behavior over land vs. water surfaces requiring separate bias correction terms. Over land, there is no significant difference between the nadir- and glint feature-dependent biases.

$$XCO_{2\,Corrected} = \frac{XCO_{2\,Raw} - FOOT[fp, mode] - FEATS[mode]}{TCCON\_ADJUST[mode]}$$

Step 3) Determine global offset from TCCON (term TCCON_ADJUST)

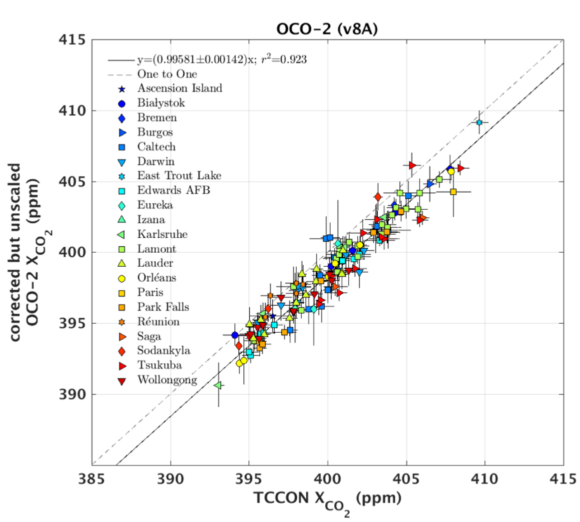


Figure 5 – OCO-2 vs TCCON Alignment Plot

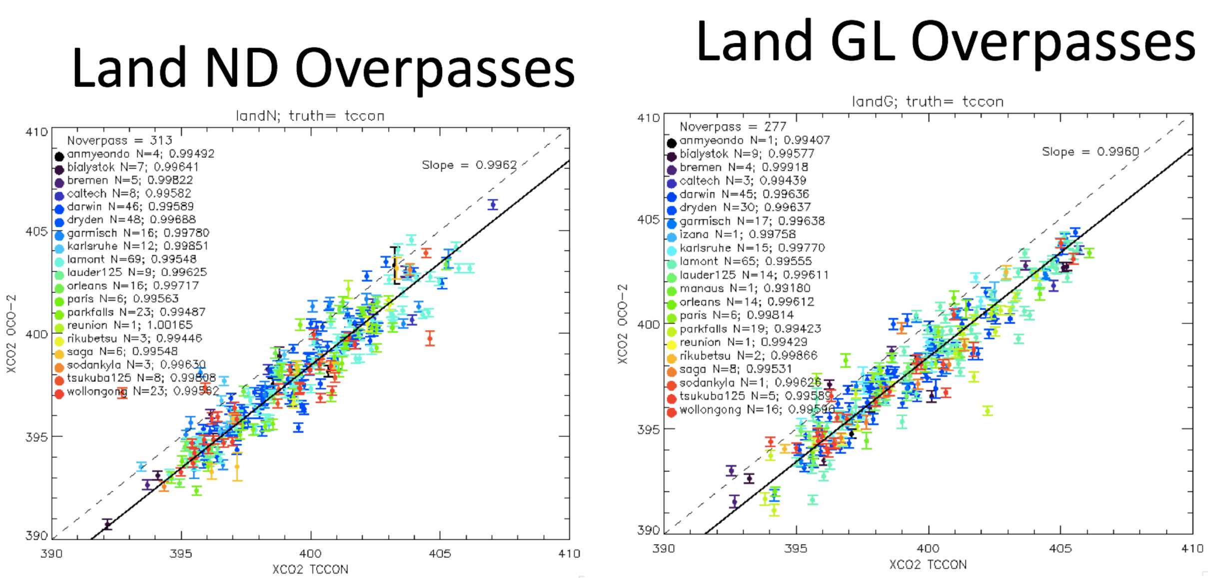
The analyses described in Steps 1 & 2 provide no estimate of the overall global bias in XCO_2. To determine the offset, we used target mode observations obtained over the TCCON sites. A linear regression between TCCON XCO_2 and the bias-corrected OCO-2 target mode XCO_2 was performed, with the intercept forced to zero (Figure 5). Overall, this analysis results in the following equation for land target: OCO-2 = (0.99581±0.00142)×

TCCON. OCO-2 retrievals are consistently lower than TCCON (about 1 ppm).

The data used to develop Figure 5 had the outlier filters applied as described in the Lite file section. In addition, the solar zenith angle and retrieval zenith angles are restricted to less than 40 degrees. Regarding TCCON data, sites are included only if there are 5 or more TCCON retrievals within one hour of the overpass, or more than 10 TCCON retrievals available within 2 hours of the overpass.

The TCCON adjustment was determined relative to the OCO-2 Land Target observations. We assume that with the restricted retrieval zenith, the land Target and Land Glint have identical bias. Future work will examine the veracity of this assumption and explore alternative methods of spreading the divisor between modes.

Land Nadir and Sea Glint are matched in time and space to Land Glint in order to propagate the TCCON alignment divisor. Coastline measurements are used to match the Land Nadir/Sea Glint datasets (Figure 6). Land Nadir and Sea Glint both produced different divisors by the equation $\frac{<XCO_2>_{mode1}}{divisor_1} = \frac{<XCO_2>_{mode2}}{divisor_2}$. Results can be found in the final Bias Correction, Table 2.



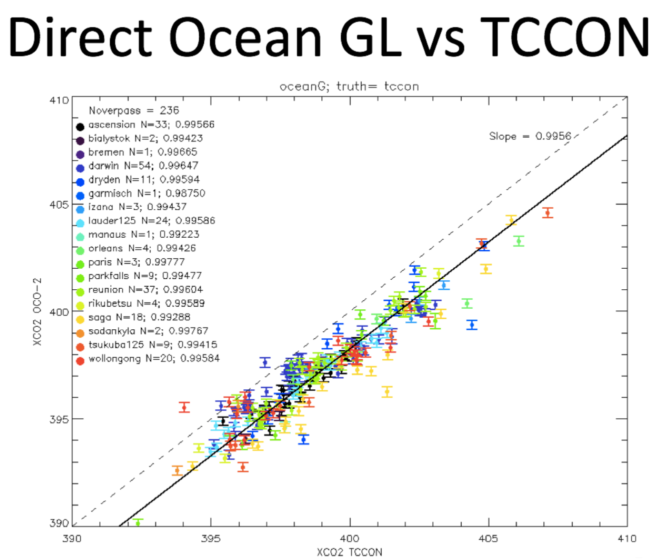


Figure 6: Scatterplots of TCCON data with nadir and glint measurements.

Step 4) XCO_2 Quality Flagging

After bias correction, additional outlier filtering is developed and applied. The xco2_quality_flag is set to "0" for good quality data and set to "1" for lower quality data. Note that this simple quality flag is a good starting point, users can see the later section on Warn Levels for a more advanced approach to data selection. Tables 3 and 4 list the details on the parameters that define the data quality flag. Figure 7 illustrates these parameters as applied to land data.

Table 2 Bias Correction Formula (for use on V8.0)

$$XCO_{2\,Corrected} = \frac{XCO_{2\,Raw} - FOOT[fp, mode] - FEATS[mode]}{TCCON\_ADJUST[mode]}$$

where:

	FOOTPRINT BIAS (FOOT) (ppm)							
Footprint (fp)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
ALL MODES	-0.36	-0.15	-0.16	-0.14	0.02	0.33	0.13	0.34

	FEATURE BIAS (FEATS) (ppm)
LAND (ALL)	– 0.36*(**dP**) – 8.5*(**DWS**) – 0.029*(**co2_grad_del** – 15)
SEA GLINT	– 0.23*(**dP**) + 0.09*(**co2_grad_del** + 6.0) [second term only applied when co2_grad_del is less than -6)

	OVERALL DIVISOR (TCCON_ADJUST)	**Method**
LAND GLINT **LAND NADIR** **LAND TARGET**	0.9958	Target is assigned Other modes derived from TCCON paired ND/GL and comparison to models
SEA GLINT	0.9955	Comparison to TCCON, coastlines, model bootstrap, and comparison to models

NOTE! This constant is needed for the L2 standard but not Lite products

	Variable definitions using full/HDF/path for L2 files
co2_grad_del	1e6 * RetrievalResults/co2_vertical_gradient_delta
dP	0.01 * (RetrievalResults/surface_pressure_fph – RetrievalResults/surface_pressure_apriori_fph)
DWS	sum (dust_aod + water_aod + salt_aod)
dust_aod (1-based)	(AerosolResults/aerosol_types_retrieved[1]) * (AerosolResults/aerosol_aod[1,1])
water_aod (1-based)	(AerosolResults/aerosol_types_retrieved[7]) * (AerosolResults/aerosol_aod[7,1)
salt_aod (1-based)	(AerosolResults/aerosol_types_retrieved[2]) * (AerosolResults/aerosol_aod[2,1)

Table 3: Quality Filters Applied to Land Soundings

All Land Soundings		
Field	**Lower Limit** (> or =)	**Upper Limit** (< or =)
Preprocessors/co2_ratio	1.00	1.025
Preprocessors/h2o_ratio	0.88	1.01
Sounding/altitude_stddev	0.0	60.0 (20.0)
Preprocessors/max_declocking_wco2	0.0	0.75
Retrieval/dp	-6.0	14.0
Preprocessors/dp_abp	-10.0	13.0 (50.0)
Retrieval/co2_grad_del	-80.0	100.0
Retrieval/albedo_sco2	0.05	0.6
Retrieval/rms_rel_wco2	0.0	0.22
Retrieval/s31	0.03	0.4
Retrieval/albedo_slope_sco2	-0.00018	0.001
Retrieval/aod_total	0.0	0.5
Retrieval/dws	0.0	0.25
Retrieval/aod_water	0.0005	0.1
Retrieval/aod_ice	0.00	0.04
Retrieval/ice_height	-0.5	0.45
Retrieval/aod_sulfate + Retrieval/aod_oc	0.0	0.3
Retrieval/aod_strataer	0.0	0.02
Retrieval/aod_oc	0.0	0.08
Retrieval/aod_seasalt	0.0	0.125

Note: Numbers in (red) are used for target-mode soundings.

Table 4: Quality Filters Applied to Ocean Glint Soundings

Ocean Glint Soundings		
Field	**Lower Limit** (> or =)	**Upper Limit** (< or =)
Retrieval/eof3_3_rel	-0.3	0.25
Preprocessors/max_declocking_wco2	0.0	0.2
Preprocessors/max_declocking_sco2	0.0	0.3
Retrieval/albedo_slope_sco2	5e-6	7e-5
Retrieval/rms_rel_wco2	0.0	0.3
Preprocessors/h2o_ratio	0.88	1.01
Preprocessors/co2_ratio	0.997	1.018
Retrieval/dp	-4.0	10.0
Retrieval/co2_grad_del	-20.0	30.0
Retrieval/windspeed	1.5	25
Preprocessors/dp_abp	-50.0	10.0
Retrieval/aod_ice	0.0	0.035

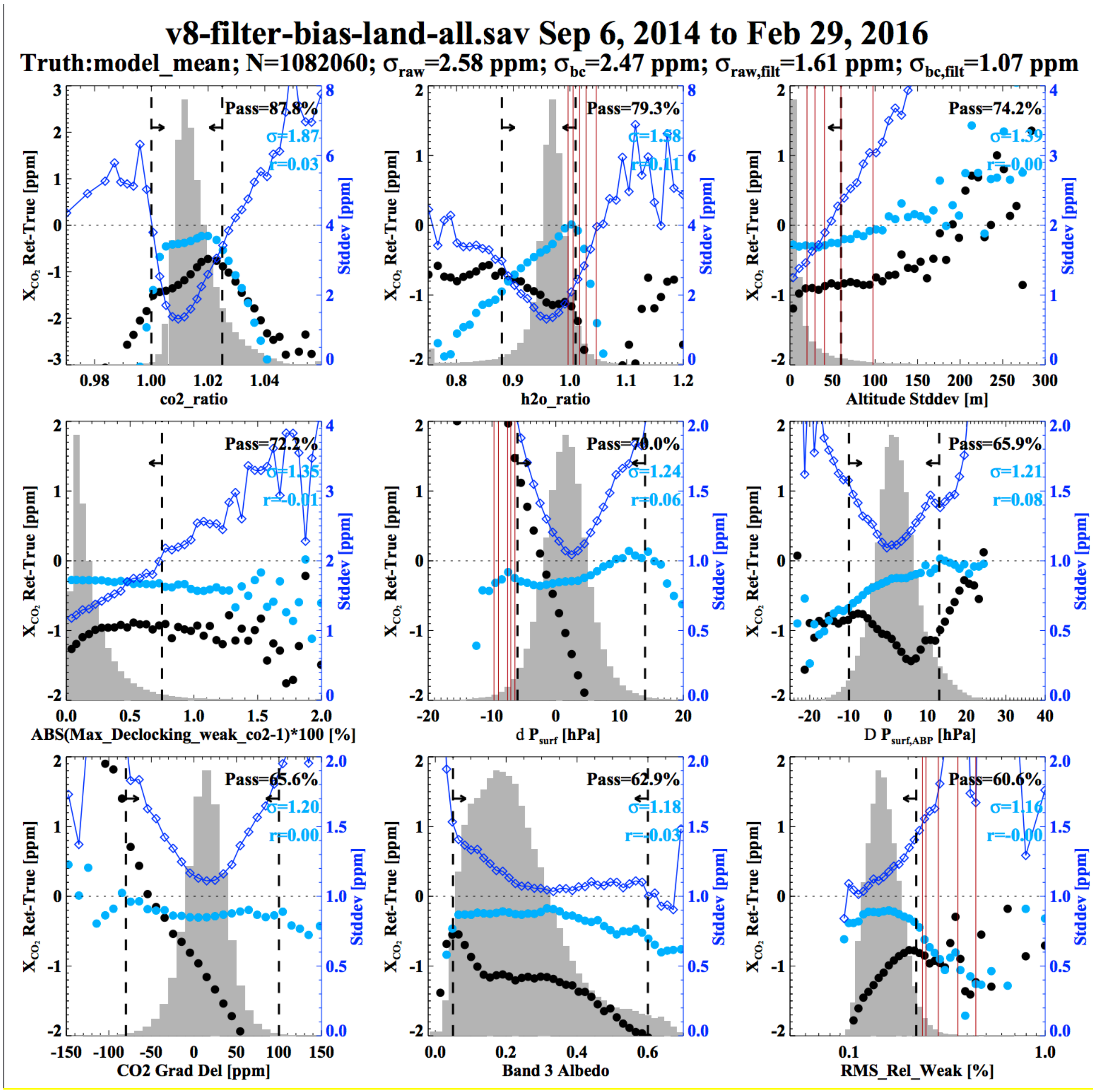


Figure 7 – Bias & Stddev of XCO_2 error as a function of selected outlier filtering variables for land observations. Here, the error is derived using the model comparison.

Histogram of Bias Terms

Figure 8 shows the histograms of bias contributions from Step 2 as well as the overall Bias Correction. The bias correction term for DWS (blue) is always negative because aerosol optical depth must be positive in the retrieval set up. A value of 1 ppm is subtracted from the overall bias determination just as it is for TCCON to match the World Meteorological Organization (WMO) *in situ* trace gas measurement scales.

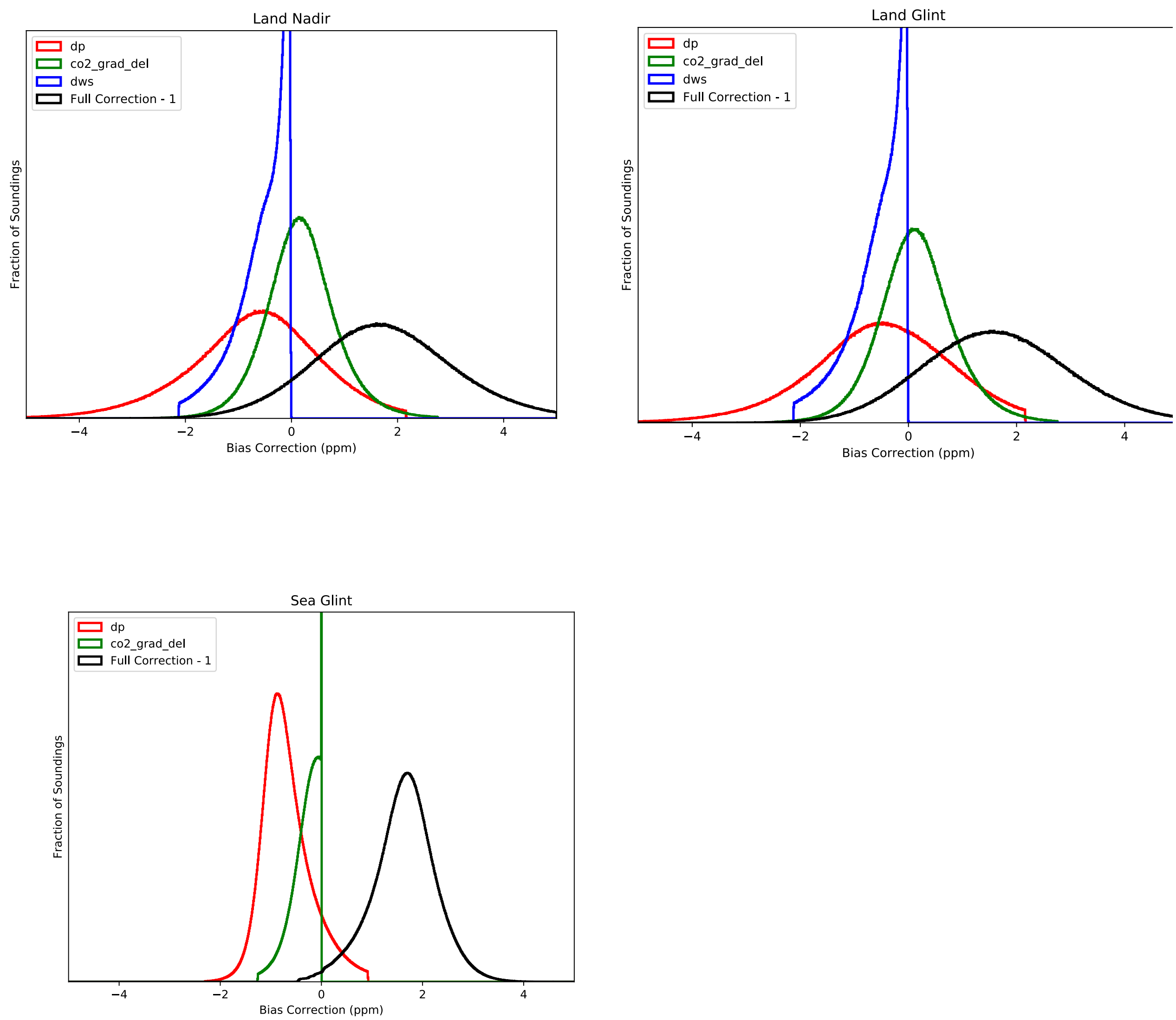


Figure 8 – Histogram of Bias Terms

Global Bias Magnitude

Figures 9 to 11 show Land Nadir, Land Glint, & Sea Glint regional biases ($XCO2_{corrected} - XCO_2$). White indicates a zero mean effect, while gray regions have no data. Extreme bias correction effects (dark red/blue, ~ 3.5 ppm) are chiefly observed in bins with low N.

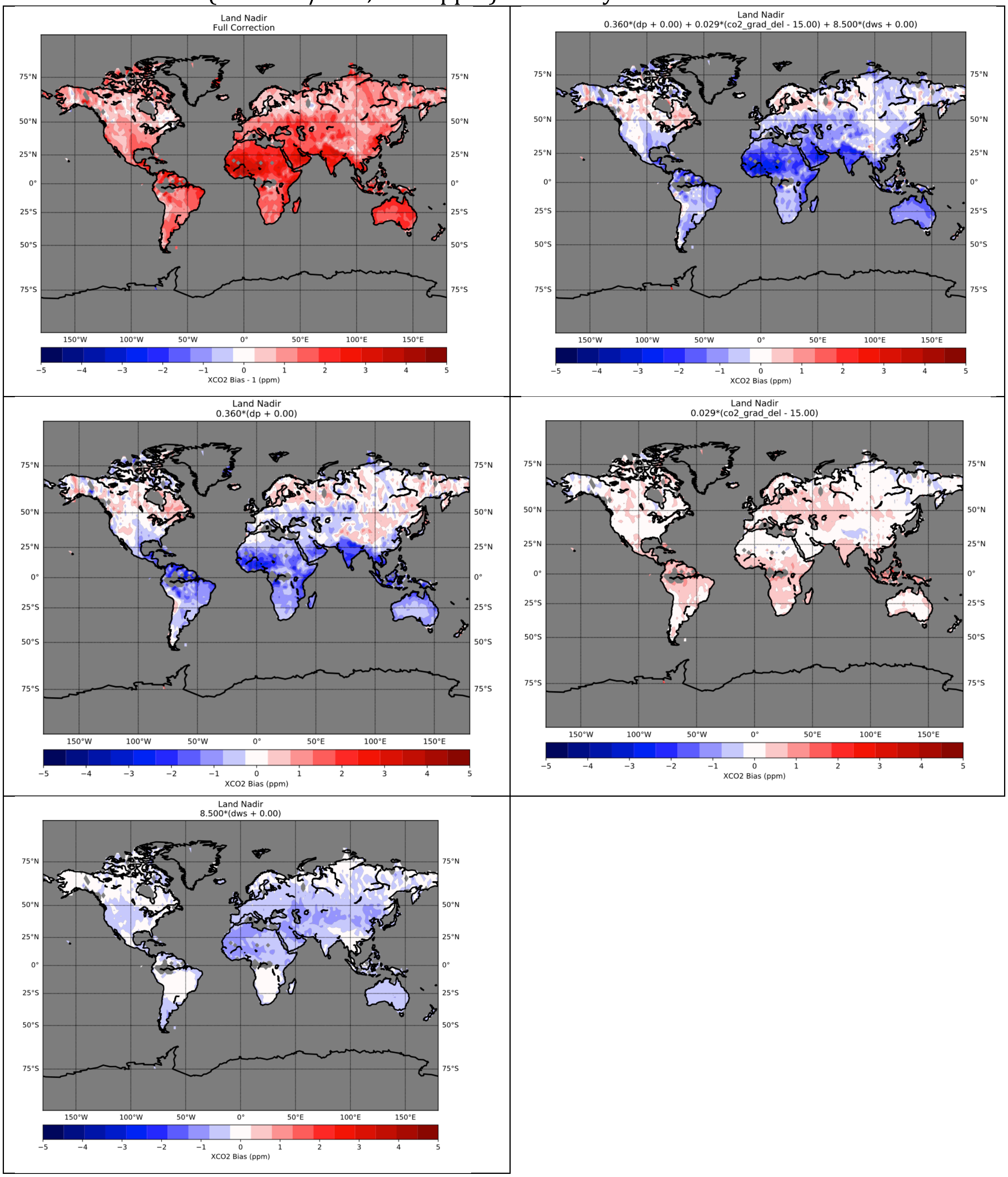


Figure 9 - Land Nadir Bias Correction Terms, Geographic Distribution

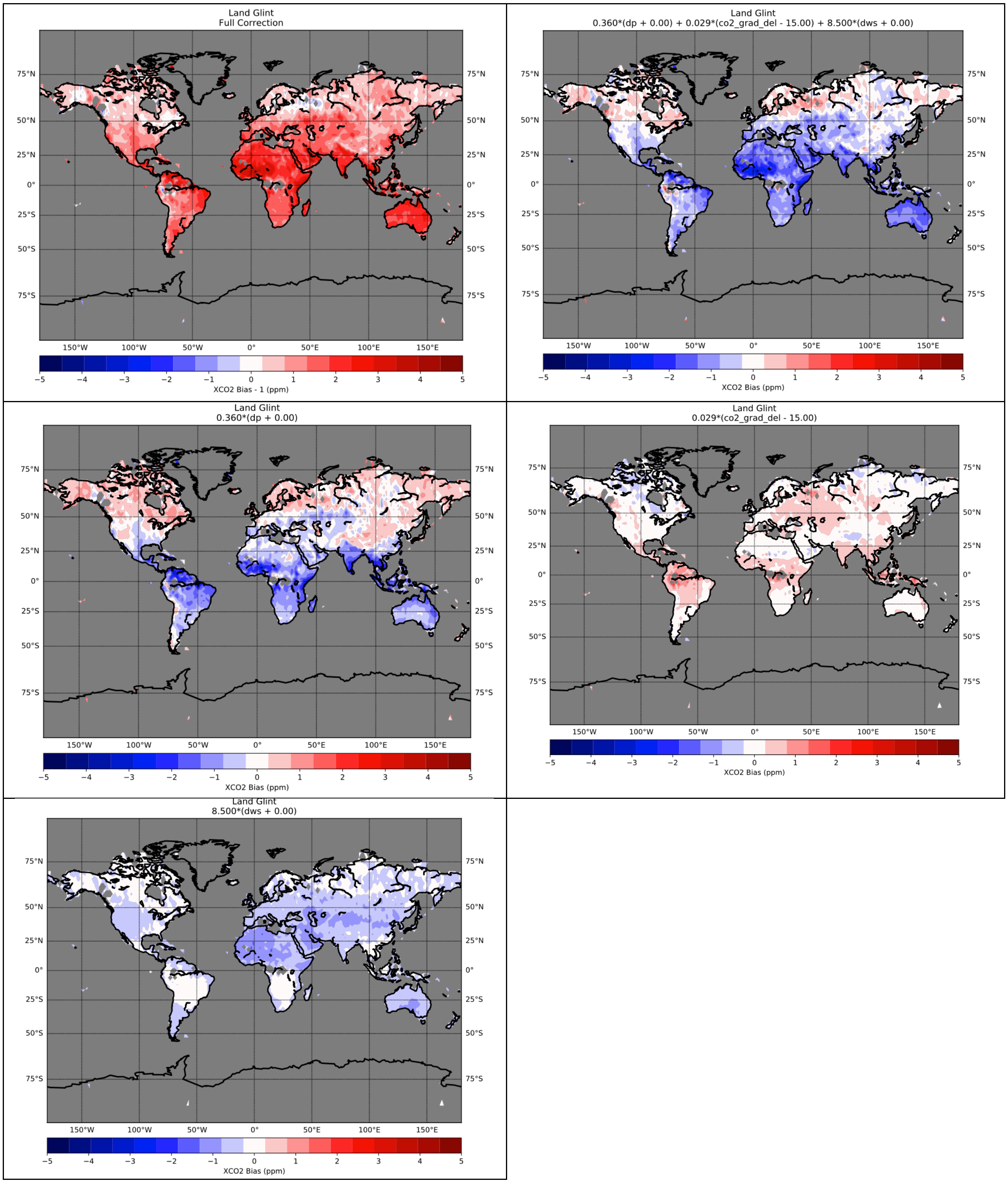


Figure 10 - Land Glint Bias Correction Terms, Geographic Distribution

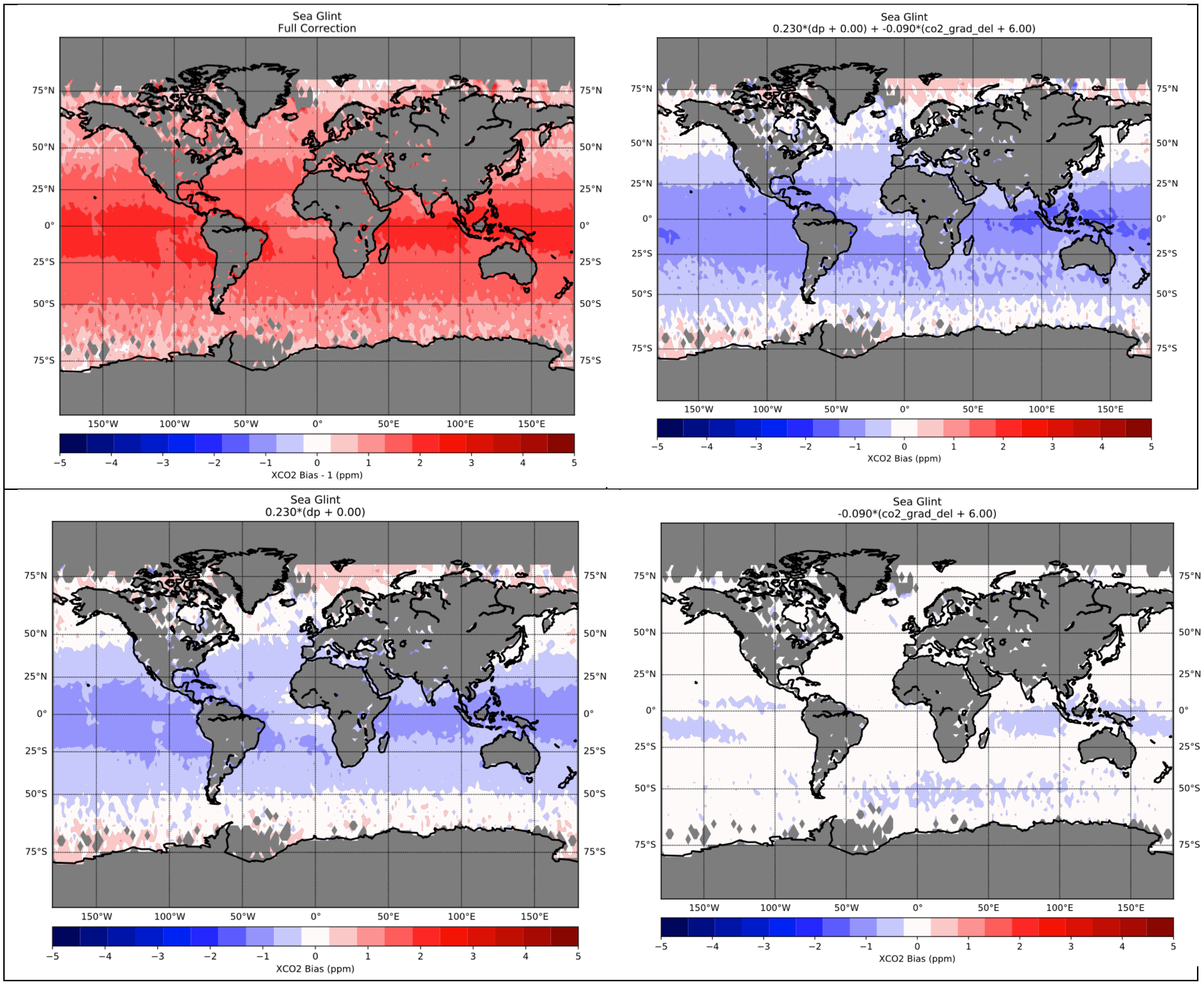


Figure 11 - Sea Glint Bias Correction Terms, Geographic Distribution

Warn Levels

Warn Levels range from 0 (includes the best 50% of the data) to 5 (including all the data), and are formulated using a set of filters that minimize the mean monthly standard deviation (MMS) of XCO_2 in locations where the atmospheric variability of XCO_2 is small.

The warn levels (0,1,2,3,4,5) correspond to (50%, 60%, 70%, 80%, 90%, and 100%) of the data. For most science data users, a warn level of 0 is a good starting point.

We use two test sets: the Southern Hemisphere Approximation (SHA) set (assumes that the entire region from -25 to -60 latitude has minimal variation in XCO_2 (Wunch et al., 2011)) and the Small Area Analysis (SAA) set (assumes that all soundings within a 0.89 degrees latitude span and identical orbit track have the same XCO_2).

The creation of WLs relies on a hyper-dimensional filter and a genetic algorithm that optimizes filter performance for every 0.1% increment of data accepted (transparency). Mandrake *et al*. (2013) describes this technique in detail. For OCO-2 V8 data, the WLs are calculated separately for each measurement mode (nadir land, glint land, glint water, and land target). Land modes all behaved the same, so there is only one set of land criteria.

Table 5 reports the features derived from the L2 and preprocessing output that were commonly correlated with XCO_2 variability in the two test sets. Many other features could be used, but we have opted for the simplest filter. The fields with the label Mandrake are ones that were calculated specifically for warn level development, and they are not in the L2Std files, but they are in the Lite files.

Table 5 – Features selected for Warn Level Development

WATER GLINT:

<L2/RetrievalResults/co2_vertical_gradient_delta
>L2/RetrievalResults/co2_vertical_gradient_delta
>L2/AlbedoResults/albedo_weak_co2_fph
<L2/AlbedoResults/albedo_slope_strong_co2
>Mandrake/abs_minus_1_max_declock_strong_co2

LAND (ALL MODES):

>Mandrake/aerosol_log_dustwatersalt_large_aod
<Mandrake/dP_fph
>L2/RetrievalGeometry/retrieval_surface_roughness
>L2/PreprocessingResults/h2o_ratio_idp
>L2/SpectralParameters/relative_residual_mean_square_weak_co2

Table 6 show the specific values that have been used to define the WLs for V8. These WLs have already been calculated and inserted into the V8 Lite files; users do not need to calculate WLs directly unless they are using the V8 L2Std files where the WL variable is assigned a fill value.

How to Use Warn Levels

The basic procedure for use of WLs is outlined in Table 2. A user first decides how much data volume or regional/global coverage they require. Alternately, she can decide how much of an error metric is tolerable (trusted XCO_2 comparison, regional XCO_2 scatter, bias deviation, extrema population presence, or presence of other anomalous sounding behaviors). The WL is then selected that balances the transparency with the error tolerance. The user has then tuned a personal filter for the investigation at hand.

Table 2: Basic Procedure for Warn Level Usage

1	Decide requirements beforehand: how much data volume / coverage or scatter / error is needed / tolerable?	
2	Begin admitting WL=0, 1, 2, … into project. Monitor above statistics.	
3	Stop when data volume / coverage are acceptable, or when scatter / error become intolerable (then back off).	

Note that WL's are almost always used Inclusively (meaning that using WL 5 is defined as using all data specified by WL <= 5). This is the proper usage for data filtration. Using a specific WL by itself (data for which WL == 2 alone) is called an Exclusive WL and is sometimes useful for finding the WL at which certain confounding forces appear. By convention, such Exclusive WL's should always be explicitly named to avoid confusion.

WL Case 1: Regional Study

Here, a user investigates a difficult environment (e.g. a plume emitted from a polluted city). We wish to harness the WLs to remove the truly useless soundings but still keep interesting yet difficult soundings. The standard procedure of Table 2 is used in the restricted region, watching carefully for the appearance of the plume and associated city pollution. Once the observations to study are clearly present, further WLs may be seen to start including clouds and other non-plume-like soundings. The user therefore backs off the included WLs until a happy medium between plume and unwanted contamination is reached. This method is similar to tuning the contrast in an image, ensuring clear viewing of the desired pattern but not over-emphasizing noise.

Case 2: Uniform Global Study

For this analysis, a user requires uniform global coverage rather than dense coverage of easy regions (e.g. deserts) and sparse coverage of difficult regions (e.g. tropics). The user would define a global grid of bins to fill with the highest quality data until each bin reaches its designated data volume goal. As in Table 2, the co-located data added to each bin is always added in order of WL from lowest to highest. At the end of the process, the soundings selected by the grid represent a spatially uniform collection of the most trusted soundings per region. Some troublesome regions will therefore consist of higher WL soundings or none at all where no alternatives were available, while easier regions will only select the most pristine soundings. This is a powerful selection method that allows the user to dial-in the precise spatial coverage desired for their application with the assurance of using the best quality data available.

Characterizing Warn Level Behavior

Warn Levels and XCO_2 characteristics

Warn Levels are designed to minimize the variance of XCO_2 in regions of small atmospheric variability. However, the signal that WL's reduce is so clearly evident that even in locations with significant, physical atmospheric variability or entire global datasets demonstrate the reduction of XCO_2 variance with respect to WL filtration. In figure 12, we show the warn level metric for V8 sea glint and land dataset as a function of the percent of data retained. The markers on the lines correspond to the V8 warn levels, which were defined very differently in V8 compared to v7. The first warn level (WL0) captures the best 50% of the data, where the data characteristics are very similar. As warn level increases, the standard deviation and comparisons metrics worsen. They appear to worsen rather monotonically up to WL4 (which includes 90% of the data). The last 10% of data has much worse performance.

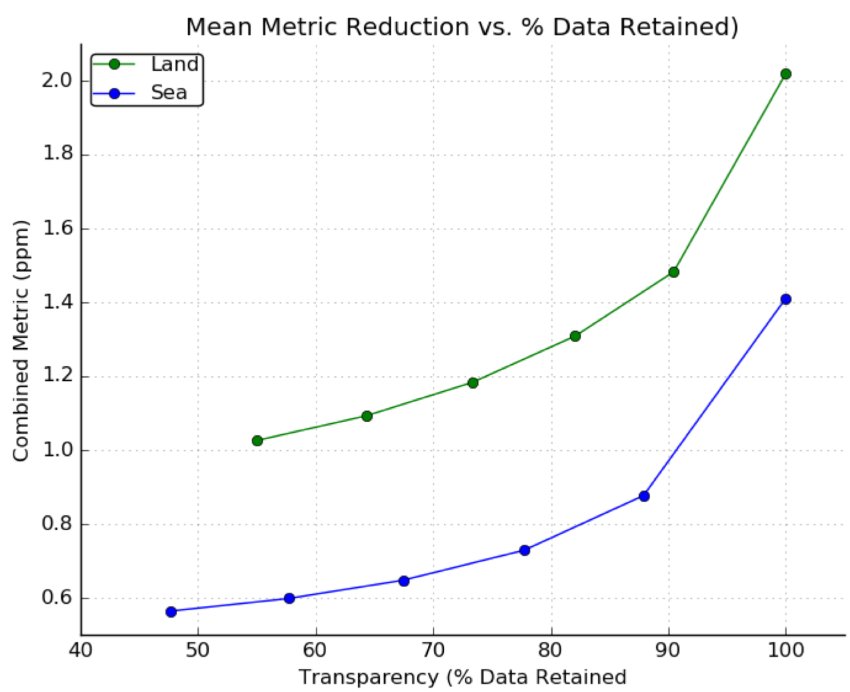


Figure 12: XCO_2 Bias and Scatter as a function of Warn Level

Warn Level Spatial Characteristics

In a future update of the documentation, we will include maps that show the spatial data density as a function of warn levels. The dataset that is used for warn level development is not dense enough to do this effectively, and at the time of writing, we do not have global, full month warn levels available.
But, we learned from v7 that selection of data by warn level impacts the data density. Typically, with v7, as warn level is decreased and overall data density is decreased, the latitudinal data density also decreases. We have not fully characterized this for V8, but if you use the warn levels for data selection, we strongly encourage you to analyze the spatial coverage.

Table 6: Values used for Warn Level determination

MODE	WL0	WL1	WL2	WL3	WL4
SEA_GL:					
<L2/RetrievalResults/co2_vertical_gradient_delta	-1.18E-05	-1.26E-05	-1.42E-05	-1.60E-05	-1.78E-05
>L2/RetrievalResults/co2_vertical_gradient_delta	2.40E-06	5.15E-06	9.63E-06	1.61E-05	2.73E-05
>L2/AlbedoResults/albedo_weak_co2_fph	0.04152818	0.04290641	0.04870763	0.05159356	0.183427
<L2/AlbedoResults/albedo_slope_strong_co2	9.11E-06	6.77E-06	5.06E-06	8.75E-07	-1.53E-05
>Mandrake/abs_minus_1_max_declock_strong_co2	0.00188552	0.002298161	0.002635343	0.00462906	0.009252626
LND_AL:					
>Mandrake/aerosol_log_dustwatersalt_large_aod	-0.8263409	-0.6938695	-0.619922	-0.5784207	-0.05069106
<Mandrake/dP_fph	-6.404422	-7.054969	-7.561389	-8.995695	-9.690548
>L2/RetrievalGeometry/retrieval_surface_roughness	19.90433	29.2552	40.46891	59.79335	97.43734
>L2/PreprocessingResults/h2o_ratio_idp	0.9966815	1.005532	1.017087	1.028502	1.046504
>L2/SpectralParameters/relative_residual_mean_square_weak_co2	0.002365796	0.002463946	0.002850933	0.003588029	0.00442925

Format Specification

OCO-2 B8 Lite Files

Overview Information

The OCO-2 L2 Lite files contain a subset of the information in the standard OCO-2 L2 product. They are meant to be significantly smaller but still contain all necessary information for typical science analyses. In addition, they have some value added:

- Only contain L2 soundings that converged
- They include a nominal recommended filtering flag (xco2_quality_flag)
- They contain a set of "warn levels" which allows the user to tune the level of data quality desired.
- They include the recommended bias correction already applied to XCO_2 (the XCO_2 without bias correction is also contained in the Lite files)

There is one file per day, for each day that had at least one retrieved sounding.

The OCO-2 Lite files are in the netCDF-4 format (http://www.unidata.ucar.edu/software/netcdf/docs/netcdf/NetCDF_002d4-Format.html). Because netCDF-4 is a subset of HDF-5, the files may be read with both netCDF and HDF software.

Generally speaking, each field in the file is described in the *Attributes* of that field within the file itself. Descriptions for selected fields are given below, but please be sure to read the *Attributes* of each used field within the actual Lite file.

After this, we describe the filtering and bias correction approach.

File Structure & Fields

The primary variables that most users will need exist at the main level. In addition, there are some additional variables that certain users might want, contained in three groups within the file: Preprocessors, Retrieval, and Sounding. Some NetCDF readers may not see these groups; if this happens, please update your NetCDF reader or use an HDF-5 reader.

1. **Main Level Variables**

   - ***latitude*** The latitude at the center of the sounding field-of-view.
     Parent Field: L2s/RetrievalGeometry/retrieval_latitude

- ***longitude*** The longitude at the center of the sounding field-of-view.
  Parent Field: L2s/RetrievalGeometry/retrieval_longitude

- ***vertex_latitude*** The latitude at each of the corners of the parallelogram that defines the field-of-view.
  Parent Field: L2s/RetrievalGeometry/retrieval_vertex_latitude

- ***vertex_longitude*** The longitude at each of the corners of the parallelogram that defines the field-of-view.
  Parent Field: L2s/RetrievalGeometry/retrieval_vertex_longitude

- ***time*** The time of the sounding in seconds since 1970-01-01 00:00:00 UTC.
  Parent Field: None (computed from RetrievalHeader/retrieval_time_string)

- ***date*** The full date and time of the sounding in UTC, organized as [year,month,day,hour,minute,second,milliseconds]. This information is redundant with that from the *time* variable.
  Parent Field: None (computed from RetrievalHeader/retrieval_time_string)

- ***solar_zenith_angle*** The solar zenith angle (in degrees) at the target.
  Parent Field: L2s/RetrievalGeometry/retrieval_solar_zenith

- ***sensor_zenith_angle*** The satellite zenith angle (in degrees) at the target.
  Parent Field: L2s/RetrievalGeometry/retrieval_zenith

- ***xco2*** The bias-corrected XCO_2 (in units of ppm). This *should be used for science analysis.* The bias correction formulae are contained in the metadata of the file.
  Parent Field: None (derived using bias-correction formula)

- ***xco2_apriori*** The prior XCO_2 assumed by the L2 retrieval, in ppm.
  *Parent Field: L2s/RetrievalResults/xco2_apriori * 1e6*

- ***xco2_uncertainty*** The posterior uncertainty in XCO_2 calculated by the L2 algorithm, in ppm. This is generally 30-50% smaller than the true retrieval uncertainty.
  *Parent Field: L2s/RetrievalResults/xco2_uncert * 1e6*

- ***xco2_quality_flag*** A simple quality flag denoting science quality data. 0=higher quality, 1=lower quality.
  Parent Field: None

- ***warn_level*** A graduated indicator of data quality. 0=highest quality; 5=lowest quality.

Parent Field: L2s/RetrievalHeader/warn_level

- ***co2_profile_apriori*** The prior profile of co2 in ppm.
  *Parent Group: L2s/RetrievalResults/co2_profile_apriori * 1e6*

- ***xco2_averaging_kernel*** The normalized column averging kernel for the retrieved XCO_2 (dimensionless).
  Parent Group: L2s/RetrievalResults/xco2_avg_kernel

- ***pressure_levels*** The retrieval pressure level grid for each sounding in hPa. Note that is simply equal to SigmaB multiplied by the surface pressure.
  *Parent Group: L2s/RetrievalResults/vector_pressure_levels * 0.01*

- ***pressure_weight*** The pressure weighting function *on levels* used in the retrieval. It has the same dimensions as both "pressure levels" and "co2_profile_apriori".
  Parent Group: L2s/RetrievalResults/pressure_weighting_function

- ***sounding_id*** The sounding_id of the sounding. For GOSAT, this is a 14-digit number defined as YYYYMMDDhhmmss. {YYYY=year, MM=month 1-12, DD=day 1-31, hh=hour 0-23, mm=minute 0-59, ss=seconds 0-59, m=hundreds of milliseconds 0-9, f=footprint number 1-8}. For OCO, it is a 16-digit number defined as YYYYMMDDhhmmssmf. {YYYY=year, MM=month 1-12, DD=day 1-31, hh=hour 0-23, mm=minute 0-59, ss=seconds 0-59, m=hundreds of milliseconds 0-9, f=footprint number 1-8}.
  Parent Field: L2s/RetrievalHeader/sounding_id

- ***source_files*** The L2Std files used to generate this file.
  Parent Group: None

- ***file_index*** The 1-based index used to identify which source file each sounding was drawn from. Ie, file_index=2 for a particular sounding means that sounding was drawn from the 2nd element of *source_files*.
  Parent Group: None

Main-Level Dimension Variables
(these variables are part of the netcdf-4 definition and will not be needed by most users)

- ***bands:*** The three OCO-*2 bands.*
- ***levels:*** The twenty vertical levels in the OCO-2 level-2 full-physics retrieval.
- ***epoch_dimension:*** Variable used for dimensioning the 7-integer *date* variable.
- ***vertices:*** The 4 vertex indices for *vertex_latitude* and *vertex_longitude*.
- ***footprints:*** The 8 footprint indices for footprint-dimensioned variables such as *Preprocessors/co2_ratio_offset_per_footprint.*

2. Preprocessors Group

This group contains information for the two OCO-2 preprocessor algorithms: The A-Band Preprocessor (ABP) and the IMAP-DOAS Preporocessor (IDP).

- ***co2_ratio***: Contains the ratio of the retrieved CO2 column from the weak Co2 band relative to that from the strong CO2 band. This ratio should be near unity. Significant departure from unity is currently used as a way to flag bad soundings (usually cloud or aerosol-contaminated). This value has also been footprint corrected using *co2_ratio_offset_per_footprint.*
Parent Field: L2s/PreprocessingResults/co2_ratio_idp (and then footprint-corrected).

- ***co2_ratio_offset_per_footprint:*** Contains the approximate offset in *co2_ratio* from the mean value across all footprints, used in the construction of *co2_ratio.*
Parent Field: none.

- ***h2o_ratio***: Contains the ratio of the retrieved H2O column from the weak CO2 band relative to that from the strong CO2 band. This ratio should be near unity. Significant departure from unity is currently used as a way to flag bad soundings (usually cloud or aerosol-contaminated). This value has also been footprint corrected using *h2o_ratio_offset_per_footprint.*
Parent Field: L2s/PreprocessingResults/h2o_ratio_idp (and then footprint-corrected).

- ***h2o_ratio_offset_per_footprint:*** Contains the approximate offset in *h2o_ratio* from the mean value across all footprints, used in the construction of *h2o_ratio.*
Parent Field: none.

- ***dp_abp***: This is the retrieved surface pressure minus the "best-guess" surface pressure from the ECMWF forecast model. This has been adjusted for a clear-sky bias as well as the local surface elevation of the observed footprint. A value of this greater than about 50 hPa absolute value typically indicates cloud or aerosol contamination.
*Parent Field: L2s/PreprocessingResults/surface_pressure_delta_abp * 1e-2*

- ***xco2_strong_idp****:* Estimate of XCO_2 using only the IMAP-DOAS strong CO2 band retrieval at 2.06 μm. The dry air column is taken from the prior. It is constructed as the ratio of the co2 column from the strong CO2 band, divided by the dry air column. Units are ppm.
Parent Fields: L2s/PreprocessingResults/co2_column_strong_band_idp, L2s/PreprocessingResults/dry_air_column_apriori_idp

- ***xco2_weak_idp**:* Estimate of XCO_2 using only the IMAP-DOAS weak CO2 band retrieval at 1.61 μm. The dry air column is taken from the prior. It is constructed as the ratio of the co2 column from the weak CO2 band, divided by the dry air column. Units are ppm.
  Parent Fields: L2s/PreprocessingResults/co2_column_weak_band_idp, L2s/PreprocessingResults/dry_air_column_apriori_idp

- ***max_declocking_o2a**:* An estimate of the absolute value of the clocking error in the O2-A band (used in the clocking correction algorithm that attempts to correct the L1b radiances for clocking errors). Expressed in percent. Typical values range from 0 to 10%.
  *Parent Field: ABS(L2s/L1bSpectralParameters/max_declocking_factor_o2-1)*100*

- ***max_declocking_wco2**:* Same as *max_declocking_o2a*, but for the weak co2 band.
  *Parent Field: ABS(L2s/L1bSpectralParameters/max_declocking_factor_strong_co2-1)*100*

- ***max_declocking_sco2**:* Same as *max_declocking_wco2*, but for the strong co2 band.
  Parent Field: L2s/L1bSpectralParameters/max_declocking_factor_strong_co2

3. **Retrieval Group**
   This group contains information from the OCO-2 level-2 retrieval algorithm. It contains many fields that will only briefly be summarized here. These are other fields that may be useful to users. Some were used for quality filtering, some for bias correction, and others for neither.

- ***xco2_raw*** is the "raw" XCO_2 retrieved by the L2 code *without bias correction*. It should not be used for science analysis.
  *Parent Field: L2s/RetrievalResults/xco2*1e6*

- ***surface_type*** Surface type used in the retrieval: 0=ocean and corresponds to a Coxmunk+Lambertian surface; 1=land and corresponds to a non-Lambertian surface with a fixed BRDF shape (this is applied to land surfaces). The BRDF is described in the L2 ATBD.
  Parent Group: L2s/RetrievalResults/surface_type (changing Coxmunk,Lambertian->0, Non-Lambertian->1)

- ***psurf*** Retrieved surface pressure (in hPa) from the L2 algorithm. Note: this can be multiplied with the variable *SigmaB* to determine the profile of pressures for any sounding.
  Parent Group: L2s/RetrievalResults/surface_pressure_fph

- ***psurf_apriori*** A priori surface pressure (in hPa) assumed by the L2 algorithm, taken originally from GEOS5-FP-IT analysis. Note: this should be used in conjunction with the variable *SigmaB_Coefficient* to determine the a priori profile of pressures.
  Parent Group: L2s/RetrievalResults/surface_pressure_apriori_fph

- ***dp*** The difference *psurf – psurf_apriori*, in hPa. This variable is used in the XCO_2 bias correction over both land and water surfaces.
  Parent Group: None.

- ***tcwv*** Retrieved Total Column Water Vapor (TWCV) in units of kg m^{-2}.
  *Parent Group: L2s/RetrievalResults/retrieved_h2o_column * (0.0180153/6.0221415e23). The latter is required to convert from molecules of h2o per m^2 to kg h2o per m^2.*

- ***tcwv_apriori*** A priori value of the TCWV derived from the prior h2o profile in units of kg m^{-2}. Obtained by dividing the retrieved *tcwv* by the retrieved *h2o_scale* factor.
  Parent Group: RetrievalResults/h2o_scale_factor (along with tcwv).

- ***tcwv_uncertainty*** Noise-driven uncertainty on the retrieved TWCV in kg m^{-2}. Obtained from the product of *tcwv_apriori* times the posterior uncertainty on the *h2o_scale* factor.
  Parent Group: RetrievalResults/h2o_scale_factor_uncert

- ***land_brdf_weight_o2a*** Retrieved amplitude of the land BRDF at the band 1 reference wavelength (0.77 μm) . The land BRDF shape is fixed for all land surfaces, and is detailed in the L2 ATBD.
  Parent Group: L2s/BRDFResults/brdf_weight_o2

- ***land_brdf_weight_wco2*** Retrieved amplitude of the land BRDF at the band 2 reference wavelength (1.615 μm) . The land BRDF shape is fixed for all land surfaces, and is detailed in the L2 ATBD.
  Parent Group: L2s/BRDFResults/brdf_weight_weak_co2

- ***land_brdf_weight_sco2*** Retrieved amplitude of the land BRDF at the band 3 reference wavelength (2.06 μm) . The land BRDF shape is fixed for all land surfaces, and is detailed in the L2 ATBD.
  Parent Group: L2s/BRDFResults/brdf_weight_strong_co2

- ***albedo_o2a*** Over-land retrievals: Surface reflectance at a reference wavelength in band 1 (0.77 μm) in the primary scattering geometry (sun->ground->sensor) derived from the retrieved BRDF. Over-water retrievals: Retrieved Lambertian albedo at the band 1 reference wavelength.

Parent Group: L2s/AlbedoResults/albedo_o2_fph (water), L2s/BRDFResults/brdf_reflectance_o2 (land).

- ***albedo_wco2*** Over-land retrievals: Surface reflectance at a reference wavelength in band 2 (1.615 μm) in the primary scattering geometry (sun->ground->sensor) derived from the retrieved BRDF. Over-water retrievals: Retrieved Lambertian albedo at the band 2 reference wavelength.
Parent Group: L2s/AlbedoResults/albedo_weak_co2_fph (water), L2s/BRDFResults/brdf_reflectance_weak_co2 (land).

- ***albedo_sco2*** Over-land retrievals: Surface reflectance at a reference wavelength in band 3 (2.06 μm) in the primary scattering geometry (sun->ground->sensor) derived from the retrieved BRDF. Over-water retrievals: Retrieved Lambertian albedo at the band 3 reference wavelength.
Parent Group: L2s/AlbedoResults/albedo_strong_co2_fph (water), L2s/BRDFResults/brdf_reflectance_strong_co2 (land).

- ***albedo_slope_o2a*** Slope of the *albedo_o2a* term with respect to wavenumber.
Parent Group: L2s/AlbedoResults/albedo_slope_o2_fph (water), L2s/BRDFResults/brdf_reflectance_slope_o2 (land).

- ***albedo_slope_wco2*** Slope of the *albedo_wco2* term with respect to wavenumber.
Parent Group: L2s/AlbedoResults/albedo_slope_weak_co2_fph (water), L2s/BRDFResults/brdf_reflectance_slope_weak_co2 (land).

- ***albedo_slope_sco2*** Slope of the *albedo_sco2* term with respect to wavenumber.
Parent Group: L2s/AlbedoResults/albedo_slope_strong_co2_fph (water), L2s/BRDFResults/brdf_reflectance_slope_strong_co2 (land).

- ***aod_ice*** Retrieved Extinction Optical Depth of cloud ice at 0.755 μm.
Parent Group: L2s/AerosolResults/aerosol_aod[,6,1] (1-based counting)*

- ***aod_water*** Retrieved Extinction Optical Depth of cloud water at 0.755 μm.
Parent Group: L2s/AerosolResults/aerosol_aod[,7,1] (1-based counting)*

- ***aod_dust*** Retrieved Extinction Optical Depth of dust aerosol at 0.755 μm.
Parent Group: L2s/AerosolResults/aerosol_aod[,1,1] (1-based counting)*

- ***aod_seasalt*** Retrieved Extinction Optical Depth of sea salt aerosol at 0.755 μm.
Parent Group: L2s/AerosolResults/aerosol_aod[,2,1] (1-based counting)*

- ***aod_bc*** Retrieved Extinction Optical Depth of black carbon at 0.755 μm.

Parent Group: L2s/AerosolResults/aerosol__aod[,3,1] (1-based counting)*

- ***aod_oc*** Retrieved Extinction Optical Depth of organic carbon at 0.755 μm.
  Parent Group: L2s/AerosolResults/aerosol_aod[,4,1] (1-based counting)*

- ***aod_strataer*** Retrieved Extinction Optical Depth of stratospheric aerosol at 0.755 μm.
  Parent Group: L2s/ AerosolResults/aerosol_aod[,8,1] (1-based counting)*

- ***aod_sulfate*** Retrieved Extinction Optical Depth of sulfate aerosol at 0.755 μm.
  Parent Group: L2s/ AerosolResults/aerosol_aod[,5,1] (1-based counting)*

- ***aod_total*** Retrieved Extinction Optical Depth of cloud+aerosol at 0.755 μm.
  Parent Group: L2s/AerosolResults/aerosol_total_aod

- ***dws*** Given by *aod_dust + aod_water + aod_seasalt*. This is used in the XCO_2 bias correction for soundings over land.

- ***ice_height*** Retrieved central pressure of the ice layer, relative to the retrieved surface pressure.

- ***deltaT*** Retrieved offset (in Kelvin) to a priori temperature profile.
  Parent Group: L2s/RetrievalResults/temperature_offset_fph

- ***h2o_scale*** Retrieved water vapor scale factor.
  Parent Group: L2s/RetrievalResults/h2o_scale_factor

- ***co2_grad_del*** Change (between the retrieved profile and the prior profile) of the co2 dry air mole fraction difference from the surface minus that at level 13, measured in ppm. Level 13 is at a pressure P = 0.631579 Psurf. This variable is used in the XCO_2 bias correction over both land and water surfaces.
  Derived from L2s/RetrievalResults/co2_profile and co2_profile_apriori.
  If c=co2_profile and a=co2_profile_apriori, then
  *delta_grad_co2 = (c[20]-c[13])*1e6 – (a[20]-a[13])*1e6*

- ***fs*** Retrieved fluorescence in units of W m^{-2} μm^{-1} sr^{-1} at 757 nm.
  Derived from: L2s/RetrievalResults/fluorescence_at_reference.

- ***reduced_chi2_o2a*** Reduced chi-squared value of the L2 fit residuals for band 1.
  Parent Group: L2s/SpectralParameters/reduced_chi_squared_o2_fph

- ***reduced_chi2_wco2*** Reduced chi-squared value of the L2 fit residuals for band 2.
  Parent Group: L2s/SpectralParameters/reduced_chi_squared_weak_co2_fph

- ***reduced_chi2_sco2*** Reduced chi-squared value of the L2 fit residuals for band 3.
  Parent Group: L2s/SpectralParameters/reduced_chi_squared_strong_co2_fph

- ***rms_rel_wco2*** RMS of the L2 fit residuals for band 2, relative to the continuum signal, in percent.
  Parent Group:
  *L2s/SpectralParameters/relative_residual_mean_square_weak_co2*100*

- ***windspeed*** Retrieved surface wind speed (in m/s) from the L2 algorithm, over water surfaces only.
  Parent Group: L2s/RetrievalResults/wind_speed

- ***windspeed_apriori*** Prior surface wind speed (in m/s) used in the L2 algorithm, over water surfaces only. Taken from the GEOS5-FP-IT analysis.
  Parent Group: L2s/RetrievalResults/wind_speed_apriori

- ***windspeed_u_met*** Prior surface wind speed (in m/s) in the horizontal U (North-South) direction. Positive *u* means the N-S wind component is flowing to the north (is from the south). Taken from the GEOS5-FP-IT analysis. Can be used along with *windspeed_v_met* to calculate the prior wind direction.
  Parent Group: L2s/RetrievalResults/wind_speed_u_met

- ***windspeed_v_met*** Prior surface wind speed (in m/s) in the horizontal V (East-West) direction. Positive *v* means the E-W wind component is flowing to the east (is from the west). Taken from the GEOS5-FP-IT analysis. Can be used along with *windspeed_u_met* to calculate the prior wind direction.
  Parent Group: L2s/RetrievalResults/wind_speed_v_met

- ***t700*** The estimated temperature at 700 hPa for each sounding, taken from the GEOS5-FP-IT forecast and estimated using linear interpolation. Invalid for soundings in which the surface pressure is lower than 700 hPa.
  Parent Group: None.

- ***s31*** Ratio of continuum signal in the strong co2 band to that of the o2a band.
  Derived from: L2s/SpectralParameters/signal_strong_co2_fph
  (divided by)
  L2s/SpectralParameters/signal_o2_fph

- ***s32*** Ratio of continuum signal in the strong co2 band to that of the weak co2 band.
  Derived from: L2s/SpectralParameters/signal_strong_co2_fph
  (divided by)
  L2s/SpectralParameters/signal_weak_co2_fph

- ***iterations*** Number of iterations taken by the retrieval.
  Parent Group: L2s/RetrievalResults/iterations

- ***diverging_steps*** Number of diverging steps taken by the retrieval.
  Parent Group: L2s/RetrievalResults/diverging_steps

- ***eof3_3_rel*** Relative amplitude of the 3rd EOF in the strong CO2 band.
  *Parent Group: (L2s/RetrievalResults/eof_3_scale_strong_co2) / (L2s/SpectralParameters/signal_strong_co2_fph) * 1.7e19 * 100*

- ***SigmaB*** The coefficients by which to multiply *psurf* to determine the pressure at each vertical level in the profile. Note this is a single list of numbers, rather than repeated for each sounding (as all the other quantities are).

4. **Sounding Group**
   Contains all the geolocation and time information for each sounding. For GOSAT, these contain the corrected geolocation information.

- ***altitude*** The mean surface elevation in the target field of view, in meters.
  Parent Field: L2s/RetrievalGeometry/retrieval_altitude

- ***altitude_stddev*** The standard deviation of the surface elevation in the target field of view, in meters.
  Parent Field: L2s/RetrievalGeometry/retrieval_surface_roughness

- ***orbit*** is the orbit number within the current repeat cycle.
  Parent Field: L2s/Metadata/StartOrbitNumber

- ***path*** The WRS path number of the current orbit. 1-233.
  Parent Field: L2s/Metadata/StartPathNumber

- ***footprint*** The footprint number of each sounding (1-8).
  Parent Field: L2s/RetrievalHeader/sounding_index

- ***land_water_indicator*** determines the land surface properties at the field of view. 0: land; 1: water; 2: inland water; 3: mixed.
  Parent Field: L2s/RetrievalGeometry/retrieval_land_water_indicator

- ***land_fraction*** The fraction of land contained in the field-of-view for each sounding.
  Parent Field: L2s/RetrievalGeometry/retrieval_land_fraction.

- ***l1b_type*** gives the version number of the input level-1B data. (e.g. “5000”, which means B5.0.00)
  Parent Field: Derived from parent file name.

- ***operation_mode*** Nadir (0), Glint (1), Target (2), or Transition (3).
  Parent Field: Derived from Metadata/OperationMode

- ***solar_azimuth_angle*** The solar azimuth angle (in degrees) at the target, measured east of north from the point of view of an observer on the ground at the target.
  Parent Field: L2s/RetrievalGeometry/retrieval_solar_azimuth

- ***sensor_azimuth_angle*** The satellite azimuth angle (in degrees) at the target, measured east of north from the point of view of an observer on the ground at the target.
  Parent Field: L2s/RetrievalGeometry/retrieval_sensor_azimuth

- ***glint_angle*** The angle (in degrees) between the local direction to the sensor, and the direction for pure glint observation (i.e., the outgoing direction from the surface for specularly reflected solar rays).

- ***airmass*** The relative airmass of the sounding, defined as 1/cos(solar_zenith_angle) + 1/cos(sensor_zenith_angle).

- ***snr_o2a*** The estimated signal-to-noise ratio in the continuum of the O2A-band.
  Parent Field: L2s/L1bScSpectralParameters/snr_o2_l1b

- ***snr_wco2*** The estimated signal-to-noise ratio in the continuum of the weak CO_2 band.
  Parent Field: L2s/L1bScSpectralParameters/snr_weak_co2_l1b

- ***snr_sco2*** The estimated signal-to-noise ratio in the continuum of the strong CO_2 band.
  Parent Field: L2s/L1bScSpectralParameters/snr_strong_co2_l1b

Feedback

Please provide feedback and comments to us at oco2_feedback@list.jpl.nasa.gov. You can receive updates and news by subscribing to our list. Email a blank message to sympa@list.jpl.nasa.gov with the subject: subscribe oco2_updates.

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